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BRIDGING KNOWLEDGE AND INCLUSIVE ORIENTATION FOR INCLUSIVE SCIENCE EDUCATION: EVIDENCE FROM INDONESIAN PRE-SERVICE TEACHERS

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Abstract. *Inclusive science education requires teachers who value diversity and are prepared to design education that enables equitable participation in inquiry and laboratory learning. This study examined inclusion readiness among Indonesian pre-service science teachers using an Attitudes, Knowledge, and Practices (AKP)-informed framework within a sequential explanatory mixed-methods design. Survey data from 376 participants across 14 universities were analysed using MANOVA and PLS-SEM. During measurement model evaluation, the attitude and practice constructs lacked discriminant validity and were therefore combined into a single construct labelled inclusive orientation, representing pre-service teachers' affective commitment and perceived readiness to implement inclusive science teaching. Structural model results indicated that conceptual knowledge of inclusive pedagogy was positively associated with inclusive orientation, while teaching experience contributed modestly to knowledge development. Qualitative findings indicated that support for inclusion was conditional on mentoring and resources, and that inclusion was often understood as physical accessibility rather than differentiated participation in science learning. The study identifies a persistent AKP gap in which inclusion readiness reflects affective commitment more strongly than developed pedagogical competence.*

Keywords: *inclusive orientation, inclusive science education, pre-service science teachers, inclusive pedagogy, teacher readiness, self-efficacy*

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Introduction

Inclusive education is not only a policy commitment but a pedagogical demand that requires teachers to reconfigure how knowledge, participation, and classroom belonging are constructed. The success of inclusive schooling depends less on formal enrolment and more on teachers' capacity to design education that enables diverse learners to participate meaningfully. In this sense, inclusion is enacted through professional judgment, pedagogical adaptation, and sustained engagement with learner variability rather than through policy directives alone.

Globally, however, a substantial proportion of children with disabilities remain excluded from mainstream schooling, with no more than 90 million not fully participating in formal education systems (UNESCO, 2023). In Indonesia, nearly 30% remain out of school, and among those enrolled, almost half do not complete primary education (Hata et al., 2023). These numbers highlight the urgent need to strengthen teacher capacity for inclusive education. Although inclusion is widely recognised as a key to equitable schooling, its successful implementation depends heavily on teachers' professional readiness, beliefs, and willingness to engage with learner diversity (Gohar et al., 2024). Such readiness is developed through sustained exposure, professional experience, and reflective practice.

Within this broader inclusive education agenda, science education poses distinct pedagogical challenges because scientific learning is fundamentally grounded in experimental and inquiry-based practices that rely on laboratory work, hands-on investigations, safety protocols, and specialised equipment. These learning environments often assume relatively uniform sensory, motor, and cognitive capacities, which can limit meaningful participation for some learners unless instructional designs are carefully adapted (Jones & Burrell, 2022). Consequently, supportive attitudes toward inclusion do not automatically translate into inclusive science teaching practices, particularly in laboratory and inquiry-based contexts where accessibility, safety, and participation must be actively negotiated.

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The effectiveness of inclusive science education, therefore, depends not only on teachers' dispositions but also on their conceptual understanding and pedagogical competence in adapting scientific instruction. In teacher education, particularly in developing contexts such as Indonesia, institutional capacity, mentoring structures, and practicum opportunities remain uneven. As a result, pre-service teachers may develop positive orientations towards inclusion without sufficient opportunities to apply inclusive principles in authentic science learning environments.

Empirical studies have provided important insights into how teachers' attitudes and experiences shape their readiness for inclusive practice. Exposure to inclusive settings and collaboration with special educators can enhance teachers' self-efficacy and optimism about diversity (Gupta & Tandon, 2021; Lao et al., 2022). Attitudes towards inclusion, however, vary considerably. While some educators view inclusion as an opportunity to enrich teaching and foster empathy, others perceive it as an additional burden that requires substantial resources and institutional support (Kazmi et al., 2023). Teachers who frame disability as a pedagogical challenge rather than a deficit are more likely to adopt adaptive strategies and sustain motivation (Fields, 2007). In contrast, limited learning resources, unclear policy guidance, and weak school-family collaboration frequently constrain teachers' capacity to enact inclusive practices (Alharbi & Iqtadar, 2024).

Research also presents mixed findings on how demographic factors influence inclusion readiness. Some studies suggest that senior teachers tend to rely on structured, content-oriented approaches, whereas younger teachers favour more adaptive, technology-supported strategies (Espiritu & Abao-an, 2025; Falth & Selenius, 2024). Others highlight empathy and belief systems as key predictors of inclusive practice (Mahat, 2008; Navarro-Mateu et al., 2019). Conversely, further research indicates that direct interaction with students with disabilities plays a more decisive role than demographic characteristics such as age or gender in shaping teachers' readiness for inclusion (Sharma et al., 2008; Tuncay & Kizilaslan, 2022). Collectively, these findings underscore the importance of experiential and institutional factors in developing inclusive teaching competence.

In the Indonesian context, these challenges are particularly evident in the Pre-Service Teacher Training Program (PTTP). Although national reforms such as the *Merdeka Curriculum* emphasise differentiation and student-centred learning, inclusive education has not been systematically embedded in pedagogical coursework or field placements. This gap is especially pronounced in science education programmes, where disability awareness, accessibility design, and differentiated instruction are rarely integrated into laboratory work and inquiry-based learning. Consequently, many PTTP graduates demonstrate theoretical awareness of inclusion but limited practical competence to support diverse learners in science classrooms (Ediyanto & Kawai, 2023; Fernandez et al., 2023).

Despite recent policy initiatives, including Ministry of Education Regulation No. 48 (2023) on reasonable accommodation, empirical evidence on Indonesian pre-service science teachers' readiness for inclusive science teaching remains limited. Prior studies often examine isolated dimensions, such as attitudes or field experiences, without analysing how beliefs, conceptual understanding, and pedagogical practices interact in inquiry- and laboratory-based science learning (Boyle et al., 2023). Consequently, policy commitments risk outpacing pedagogical capacity, and science teacher education lacks guidance on cultivating inclusive readiness as a discipline-specific competence.

Theoretical Framework

Inclusive science education is centrally concerned with epistemic access and meaningful participation in scientific inquiry. In contrast to instructional models that emphasise content transmission, science learning is grounded in laboratory work, experimentation, and inquiry-based practices that require active engagement with materials, procedures, and scientific representations. From a critical perspective, exclusion in science education often arises not from the absence of learners in classrooms, but from educational designs that assume uniform sensory, cognitive, and motor capacities (Dewsbury, 2020; Jones & Burrell, 2022). For students with disabilities, barriers to participation are frequently embedded in laboratory routines, safety protocols, assessment practices, and representational modes rather than in individual impairments. Accordingly, inclusive science teaching requires deliberate pedagogical adaptation to ensure that all learners can meaningfully engage in knowledge construction and inquiry processes (Carlone & Johnson, 2007).

To examine how pre-service teachers are prepared for this challenge, the study draws on an integrated Attitude-Knowledge-Practice (AKP) framework, adapted from the Knowledge-Attitude-Practice (KAP) model commonly used in educational and behavioural research. Within this framework, attitudes refer to teachers'

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affective orientations toward inclusive education, knowledge denotes their conceptual understanding of inclusive pedagogy in science learning (including accessibility, differentiation, and participation), and practice refers to self-reported or intended pedagogical actions during teaching simulations or practicum experiences. Rather than assuming a linear progression from attitudes to practice, the AKP framework is used to explore how these dimensions of inclusion readiness align, or diverge, in science education contexts (Avramidis & Norwich, 2002; Mahat, 2008; Sharma et al., 2008).

The relationships among attitudes, knowledge, and practices are mediated by contextual and experiential factors, particularly self-efficacy, practicum exposure, and mentoring. Social Cognitive Theory suggests that positive attitudes may support intention, but sustained pedagogical action depends on mastery experiences, guided practice, and professional feedback (Bandura, 1997). In pre-service science teacher education, limited opportunities to experiment with inclusive laboratory and inquiry-based instruction may constrain the development of inclusive pedagogical content knowledge, even when affective commitment is high (Fränkel et al., 2023). Accordingly, this study conceptualises inclusion readiness not as a stable disposition, but as an emergent professional capacity shaped by the interaction between affective orientation, conceptual understanding, and structurally mediated opportunities for pedagogical enactment. This framework directly informs the operationalisation of the AKP constructs and the interpretation of the structural relationships examined in the quantitative analysis.

During model evaluation, attitudes and self-reported practices were not empirically distinguishable. They were therefore combined into a single construct, Inclusive Orientation, representing teachers' affective commitment and perceived readiness to enact inclusive science teaching. Although the AKP framework guided the initial conceptualisation, the final empirical model treated these domains as a single construct because discriminant validity was not achieved.

Research Focus and Questions

This study examines inclusion readiness among Indonesian pre-service science teachers by exploring their attitudes, conceptual knowledge, and perceived readiness to implement inclusive science teaching, with particular attention to laboratory- and inquiry-based contexts. This study was guided by the following research questions:

RQ1. What attitudes do pre-service science teachers hold toward inclusive science education and students with disabilities?

RQ2. To what extent do pre-service science teachers demonstrate conceptual understanding of inclusive pedagogy in science learning, including accessibility, differentiation, and participation?

RQ3. How do pre-service science teachers perceive their readiness to implement inclusive science instruction in laboratory and inquiry-based learning contexts?

RQ4. How are conceptual knowledge, teaching experience, and demographic factors associated with pre-service teachers' inclusive orientation toward teaching science inclusively?

Research Methodology

Design

This study adopted a sequential explanatory mixed-methods design to examine inclusion readiness among Indonesian pre-service science teachers. The research was conducted between March and August 2024 within PTTP across multiple Indonesian universities. Guided by an AKP framework informed by Social Cognitive Theory, the study combined quantitative and qualitative approaches to capture both structural relationships and contextual interpretations of inclusive science teaching.

The quantitative phase employed survey methods to examine patterns of inclusion readiness and to analyse the relationships among conceptual knowledge, inclusive orientation, and selected demographic variables, while the qualitative phase involved semi-structured interviews to deepen understanding of how participants perceived and enacted inclusive pedagogy in practicum and learning contexts. This design enabled a comprehensive examination of inclusion readiness by integrating statistical modelling with participants' experiential accounts.

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Participants and Context

The research population comprised pre-service science teachers enrolled in PTTP at Indonesian universities. Given the decentralised structure of teacher education in Indonesia and the absence of a national registry of pre-service science teachers, the total population size could not be precisely determined.

Participants were recruited using a stratified convenience sampling strategy. Stratification was operationalised at two levels: (a) institutional type (public and private universities) and (b) geographical region (Java and outside Java), to ensure representation across major structural variations in Indonesian teacher education. Within each stratum, participants were recruited through programme coordinators, institutional mailing lists, and professional academic networks (WhatsApp group), with survey links distributed electronically to eligible pre-service science teachers.

A total of 376 valid responses were obtained (see Table 1), exceeding minimum sample size recommendations for PLS-SEM analysis and allowing stable estimation of model parameters (Hair et al., 2019). While this sampling approach limits statistical generalisability, it is appropriate for exploratory and explanatory modelling in complex educational contexts. Accordingly, the sample is interpreted as analytically informative rather than statistically representative of all Indonesian pre-service science teachers.

Table 1
Participants' Demography (N=376)

Characteristics	Total	%
Gender		
Male	72	18.9
Female	304	81.1
Teaching experience		
No	106	28.3
Yes	270	71.7
Experience and interaction with students with disabilities		
No	204	54.1
Yes	172	45.9
Total	**376**	**100%**

For the qualitative phase, ten participants were purposively selected to reflect variation in gender, institutional type (state or private), prior teaching experience, and interaction with students with disabilities (see Table 2). This selection strategy ensured heterogeneity of perspectives and strengthened the triangulation between quantitative and qualitative findings.

Table 2
Interview Participants

Name (pseudonym)	Gender	Type of PTTP	Teaching experience	Experience and interaction with students with disabilities
Dika	Male	State	No	Yes
Andika	Male	Private	Yes	Yes
Rani	Female	Private	No	No
Siti	Female	State	No	No
Anis	Female	Private	Yes	No
Fara	Female	State	Yes	Yes
Fredi	Male	Private	Yes	Yes

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Name (pseudonym)	Gender	Type of PTTP	Teaching experience	Experience and interaction with students with disabilities
Adiba	Female	State	Yes	Yes
Rita	Female	State	Yes	Yes
Rudi	Male	State	No	Yes

Instruments

Quantitative data were collected using the Attitude, Knowledge, and Pedagogy for Inclusion (AKPI) Scale, adapted from two validated instruments: the Multidimensional Attitudes Toward Inclusive Education Scale (MATIES; Mahat, 2008) and the Teacher Attitudes Toward Inclusion Scale (TATIS; Cullen et al., 2010). The AKPI was initially designed to capture three domains aligned with the AKP framework: attitudes toward inclusive education (10 items), knowledge of inclusive pedagogy in science learning (10 items), and inclusive pedagogical practices (10 items).

Attitude items were rated on a 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5). Knowledge items assessed conceptual understanding of accessibility, differentiation, and participation in science learning using a four-point rubric from incorrect (1) to correct (4). Inclusive pedagogical practices were measured on a four-point frequency scale from never (1) to always (4), capturing participants' self-reported and intended instructional practices during teaching simulations or practicum experiences in science contexts.

During the measurement model assessment, the indicators representing attitudes and self-reported practices showed substantial empirical overlap. Because the two sets of indicators were not clearly distinguishable, they were combined into a single construct labelled inclusive orientation, representing pre-service teachers' affective commitment and perceived readiness to enact inclusive science teaching. As the practice items referred to intended or self-reported instructional behaviours rather than directly observed classroom performance, they were interpreted as indicators of teachers' perceived readiness for inclusive pedagogy.

The instrument's content validity was reviewed by a panel of three experts in inclusive education to ensure conceptual alignment with the Indonesian context of science teacher education. A pilot test involving 52 participants yielded a Cronbach's alpha coefficient of .87, indicating satisfactory internal consistency.

The qualitative phase used a semi-structured interview protocol derived from the AKP framework to explore how participants interpreted inclusion readiness in their coursework and practicum experiences. The protocol, developed by the researchers in line with the study's research questions, included open-ended prompts addressing attitudinal orientations towards inclusion, conceptual understanding of inclusive pedagogy, and reported classroom implementation strategies. Interviews were conducted individually, either face-to-face or online, depending on participants' availability, and took place in quiet settings to ensure confidentiality and audio clarity.

Procedures

Data collection was conducted in two sequential phases. In the quantitative phase, the AKPI questionnaire was administered online, yielding 376 valid responses after data screening. Participation was voluntary, and informed consent was obtained prior to completing the survey.

The qualitative phase followed quantitative analysis to clarify and deepen the interpretation of statistical patterns. Individual semi-structured interviews were conducted online, lasting approximately 90–120 minutes. All interviews were audio-recorded with participants' consent, transcribed verbatim, and verified through member checking.

Ethical Consideration

This study adhered to established ethical standards for educational research. Ethical approval was obtained from the State University Sunan Kalijaga Yogyakarta (Approval Code: B-3405.29/Un.02/L3/TL/07/2024). All participants received written information about the study's aims, procedures, and voluntary nature prior to participation. Informed consent was obtained electronically for the survey and in written form for interviews. Participants were assured of anonymity and confidentiality, with pseudonyms used in all qualitative reporting, and informed of their right to withdraw from the study at any stage without consequences.

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Data Analysis

Quantitative data were analysed using descriptive statistics, Multivariate Analysis of Variance (MANOVA), and Partial Least Squares Structural Equation Modelling (PLS-SEM). Descriptive statistics were used to examine the overall distribution of attitudes, knowledge, and reported instructional orientation toward inclusive science education. MANOVA was conducted to assess potential differences across demographic variables.

PLS-SEM was employed to examine the structural relationships among the study variables in addressing RQ4. The analysis followed established PLS-SEM procedures, beginning with evaluation of the measurement model and followed by assessment of the structural model. Measurement model evaluation included tests of internal consistency reliability (Cronbach's alpha and composite reliability), convergent validity (average variance extracted), and discriminant validity using the heterotrait–monotrait ratio (HTMT).

The structural model was subsequently evaluated by examining path coefficients, statistical significance using bootstrapping procedures, and the coefficient of determination (R^2). Given the exploratory nature of the model and the reliance on self-reported indicators of inclusive orientation, findings are interpreted cautiously and are understood as structural associations rather than causal relationships.

Qualitative data were analysed through thematic analysis, combining deductive coding based on the AKP framework with inductively generated themes. Credibility was supported through member checking, peer debriefing, and an audit trail.

Research Results

Descriptive Patterns of the Initial AKP Dimensions

To address RQ1–RQ3, a descriptive statistical analysis was conducted to examine the distribution of attitudes, knowledge, and practices across gender and teaching experience. These descriptive statistics are presented based on the initial AKP domains prior to the measurement model revision. Table 3 presents the mean and standard deviation values for each AKP dimension. The results show relatively consistent attitudes toward inclusion across gender and experience groups, with male and female participants reporting similar mean scores. Knowledge scores showed minor variation, while practice scores were slightly higher among those with teaching experience.

Table 3
Descriptive Results (Attitude, Knowledge, Practice)

Measure	Gender	Experience	*M*	*SD*	*n*
Attitude	Male	No	56.59	9.33	27
		Yes	56.13	10.31	45
	Female	No	56.96	9.53	79
		Yes	55.91	10.05	225
Knowledge	Male	No	55.56	20.82	27
		Yes	51.11	21.66	45
	Female	No	48.23	18.03	79
		Yes	51.60	17.53	225
Practice	Male	No	80.63	14.69	27
		Yes	78.07	20.10	45
	Female	No	70.29	22.79	79
		Yes	77.11	20.97	225

These descriptive trends provide an initial overview of inclusion readiness and suggest that demographic differences were limited. These patterns should also be interpreted with caution, as the three AKP dimensions were measured using different response scales and score ranges.

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Multivariate Analysis of Group Differences

A MANOVA was performed to examine group differences by gender and teaching experience. The multivariate tests, including Wilks' Lambda and Pillai's Trace (Table 4), revealed no statistically significant main effects or interaction effects (all $p > .05$).

Table 4
Multivariate Tests

Effect	Statistic	Value	*F*	*df*	Error *df*	*p*	Partial η^2
Gender	Wilks' Lambda	.984	1.958	3	370	.120	.016
Teaching Experience		.998	.261	3	370	.853	.002
Gender × Experience		.987	1.625	3	370	.183	.013

As shown in Table 5, the assumption of homogeneity of covariance matrices was met (Box's M = 16.821, p = .568), supporting the validity of the MANOVA results. Effect sizes were small across all multivariate tests, indicating limited practical differences by gender and teaching experience.

Table 5
Box's Test of Equality of Covariance Matrices

Test	Box's M	*F*	*df1*	*df2*	*p*
Equality of Covariance Matrices	16.821	.909	18	43648.176	.568

Partial Least Squares Structural Equation Modelling (PLS-SEM)

To address RQ4, the relationships among knowledge, inclusive orientation, gender, and teaching experience were examined using PLS-SEM. The analysis followed a two-step approach, comprising the evaluation of the measurement and structural models.

Measurement Model (Outer Model)

All retained indicators showed loadings above the recommended threshold of .70, indicating satisfactory indicator reliability. The inclusive orientation construct demonstrated strong internal consistency and convergent validity, with Cronbach's alpha and composite reliability exceeding recommended levels, and AVEs above .50, as shown in Table 6.

Table 6
Outer Loadings for Each Construct

Construct	Indicator	Loading
Knowledge	P10	.743
	P3	.838
	P5	.739
	P6	.848
	P8	.799

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ISSN 2538–7138 /Online/

Construct	Indicator	Loading
Inclusive Orientation	PR1	.814
	PR10	.829
	PR2	.770
	PR3	.796
	PR4	.863
	PR5	.874
	PR6	.908
	PR7	.898
	PR8	.845
	PR9	.802
	S1	.820
	S10	.825
	S3	.799
	S4	.863
	S5	.863
	S6	.903
	S7	.894
	S8	.840
	S9	.801
	S2	.763

The revised measurement model demonstrates strong internal consistency and convergent validity. The inclusive orientation construct shows a Cronbach's alpha of .967 and a composite reliability of .971, with an AVE exceeding the recommended threshold (see Table 7). These values indicate that the indicators reliably capture the underlying construct of inclusive orientation. In addition, as shown in Table 8, the SRMR values indicate acceptable model fit according to the commonly recommended threshold of .10 for PLS-SEM models (Hair et al., 2019).

Table 7
Construct Reliability and Validity

Construct	Cronbach's α	Composite Reliability (CR)	AVE	Interpretation
Knowledge	.855	.895	.632	Good reliability
Inclusive Orientation	.967	.971	.664	Excellent reliability

Table 8
Standardised Root Mean Square Residual (SRMR)

Parameter	Saturated model	Estimated model
SRMR	.067	.097
d_ULS	1.720	3.584
d_G	n/a	n/a
Chi-square	∞	∞
NFI	n/a	n/a

Discriminant validity was assessed using the HTMT, which has been shown to be a more reliable criterion than the traditional Fornell–Larcker approach (Henseler et al., 2015). Following the guidelines proposed by Hair et al.

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(2019), a stringent threshold of .85 was applied. The analysis showed that the HTMT value between the attitude and practice constructs exceeded the recommended threshold (HTMT = 1.041) as shown in Table 9, indicating a very high level of empirical overlap between the two constructs. This finding indicates that the indicators intended to measure inclusive pedagogical practices also capture affective orientations toward inclusive education, making the two constructs empirically indistinguishable.

To address construct redundancy, the attitude and practice constructs were combined into a single new construct, labelled inclusive orientation. This construct represents both the affective commitment and the perceived readiness of pre-service science teachers to implement inclusive science teaching. This approach is consistent with the recommendations of Hair et al. (2019), which suggest merging constructs when discriminant validity is not achieved and when conceptual alignment exists among the constructs.

Table 9
Heterotrait-monotrait ratio (HTMT)

Teaching Experience ↔ Gender	.101	Practice ↔ Knowledge	.148
Knowledge ↔ Gender	.057	Attitude ↔ Gender	.078
Knowledge ↔ Teaching Experience	.201	Attitude ↔ Teaching Experience	.087
Practice ↔ Gender	.071	Attitude ↔ Knowledge	.137
Practice ↔ Teaching Experience	.093	Attitude ↔ Practice	1.041

Because discriminant validity was not achieved, the original three-construct specification was not retained for structural interpretation. The revised structural model, therefore, used inclusive orientation in place of the separate attitude and practice constructs.

Structural Model (Inner Model)

After establishing measurement validity, the structural model was evaluated to test the relationships among knowledge, inclusive orientation, gender, and teaching experience. Figure 1 presents the estimated structural model, and Table 10 summarises the path coefficients.

Figure 1
SEM Model of Knowledge and Inclusive Orientation

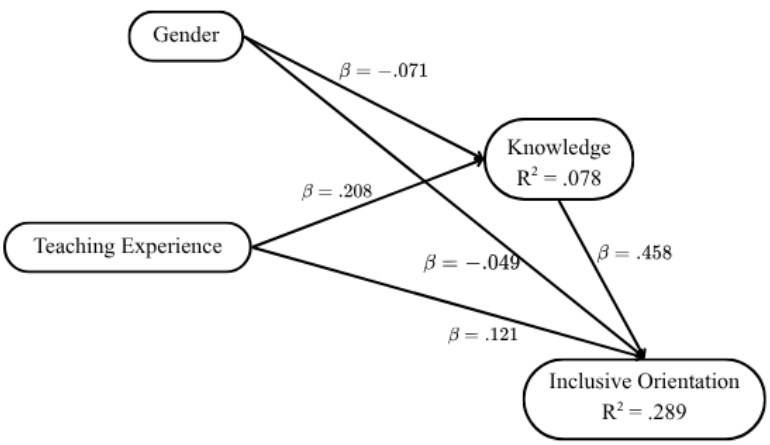

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Table 10
Path Coefficients and Significance

Path	β	95% CI	Significance
Knowledge → Inclusive orientation	.458	(.319, .573)	Supported
Teaching Experience → Knowledge	.208	(.097, .316)	Supported
Teaching Experience → Inclusive orientation	.121	(-.014, .253)	Not supported
Gender → Knowledge	-.071	(-.198, .058)	Not supported
Gender → Inclusive orientation	-.049	(-.162, .062)	Not supported

The structural model results indicate that knowledge of inclusive pedagogy is positively associated with pre-service teachers' Inclusive Orientation ($\beta = .458$, $p < .05$). This suggests that conceptual understanding of accessibility, differentiation, and participation in science learning contributes to teachers' readiness to implement inclusive teaching strategies.

Teaching experience shows a significant positive relationship with knowledge ($\beta = .208$, $p < .05$), indicating that practical teaching exposure may support the development of conceptual understanding of inclusive pedagogy. However, teaching experience does not demonstrate a significant direct relationship with inclusive orientation, suggesting that practical exposure alone may not be sufficient to foster inclusive readiness without accompanying pedagogical knowledge.

Gender does not show a significant relationship with either knowledge or inclusive orientation, suggesting that readiness for inclusive science education is more strongly shaped by professional and pedagogical factors than by demographic characteristics.

Table 11
R^2 Values for Endogenous Constructs

Construct	R^2	Interpretation
Knowledge	.078	Low explanatory power
Inclusive Orientation	.289	Moderate explanatory power

The revised structural model explained 28.9% of the variance in inclusive orientation and 7.8% of the variance in knowledge, indicating moderate explanatory power for inclusive orientation and limited explanatory power for knowledge.

Qualitative Findings: Thematic Narrative Synthesis

To deepen the interpretation of the quantitative results, qualitative interviews were analysed to explore how pre-service teachers perceived and enacted inclusion in practice (RQ1–RQ3). Four overarching themes emerged from the thematic analysis, providing nuanced explanations for why supportive orientation toward inclusion did not consistently translate into well-developed inclusive pedagogical competence.

Theme 1. Conditional support for inclusion

Most participants expressed positive yet conditional attitudes towards inclusion, shaped by empathy, coursework exposure, and perceived contextual readiness. Their acceptance of inclusion was sincere but limited by confidence and experience. Adiba reflected, "*In this PTTP programme, I received materials on inclusive education… From that course, I learned that students have unique characteristics and diverse needs, including those with disabilities. Our task is to support that diversity.*" Her understanding stemmed mainly from theoretical exposure

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rather than direct practice. Fredi shared a classroom experience that reinforced this awareness: "*I once taught a student with a visual impairment. He didn't face major obstacles as long as we provided access to the materials he needed.*" These narratives indicate that inclusion was viewed as achievable only under supportive conditions, such as adequate access or structured guidance. Dika summarised this stance: "*I generally agree that students with disabilities should attend regular schools. However, for those who have difficulties accessing school buildings, like students using wheelchairs, it might be better for them to attend special schools.*"

Theme 2. Practical Challenges

While participants valued inclusion, they identified multiple barriers to its implementation in practice. The most frequent challenges were inadequate facilities, a lack of assistive tools, and minimal professional support. Rudi noted, "*Facilities in schools are still limited, and sometimes we don't even know what tools or media should be used. It makes inclusion difficult to practice.*" Participants also highlighted the absence of trained personnel and limited mechanisms for collaboration, noting that teachers often rely on external support, such as special education staff or classroom assistants. Beyond structural limitations, several participants described emotional strain and uncertainty about how to respond to diverse learners. Andika shared, "*What frustrates me is when students with disabilities don't want to participate, even though I've tried to encourage them. It sometimes makes me feel burdened.*" These accounts illustrate that teachers' challenges were not only material but also psychological and organisational. The lack of clear guidance, accessible resources, and mentoring opportunities made inclusion appear demanding and unsustainable. Overall, participants perceived inclusion as a worthwhile but exhausting process that depended heavily on systemic and institutional support.

Theme 3. Limited Understanding of Inclusion

Participants expressed a willingness to teach inclusively but faced significant challenges in translating their ideas into classroom or laboratory practice. Most described inclusion in general terms and had limited ability to design differentiated learning or adapt inquiry-based activities for diverse learners. Their explanations often reflected uncertainty about how to modify experiments, materials, or assessment methods to ensure participation. Several participants indicated that inclusion was desirable but beyond their personal capacity, particularly in scientific settings that require preparation, supervision, and safety management. Some described frustration when inclusive efforts did not lead to active engagement, suggesting that their understanding of inclusion remained more moral than methodological. A few participants, however, demonstrated a growing awareness of differentiation and flexible design. Fara reflected, "*When we prepare lessons, we need to think of different ways for students to understand and engage, not only for those with disabilities but for everyone in the class.*" Her statement shows an emerging understanding of inclusive pedagogy that moves beyond moral acceptance towards practical adaptation. The data show that participants' conceptual understanding of inclusion remained fragmented, emphasising acceptance over adaptive design and collaboration.

Theme 4. Delegated Responsibility

Delegation of responsibility emerged as a distinct theme, illustrating how participants positioned themselves within inclusive science classrooms. Many viewed inclusive teaching as a specialised task for professionals in special education rather than a shared duty. Anis stated, "*It's unrealistic for one teacher to focus on students with disabilities; we need a special education teacher.*" This view reflects a perceived division of labour and a lack of collective ownership of inclusion. Participants commonly described inclusion as feasible only with the help of assistants or additional personnel, highlighting the need for systemic collaboration rather than isolated effort. However, a smaller group demonstrated more proactive and inclusive orientations. Fara explained, "*Even if there are no students with disabilities, we still need to develop diverse strategies so that every student can access the lesson.*" Her comment contrasts sharply with the delegation mindset and aligns with the principles of the *Merdeka Curriculum*, which encourage flexibility and teacher autonomy. This variation suggests that pre-service teachers are situated along a continuum from dependence to professional agency, reflecting varying levels of pedagogical confidence and institutional support.

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Discussion

Inclusive Orientation and Conditional Readiness for Inclusion

The findings indicate that pre-service science teachers generally express supportive orientations toward inclusive education. However, qualitative evidence shows that this orientation is often conditional and shaped by perceptions of institutional support, access to mentoring, and the availability of instructional resources. Rather than reflecting fully developed pedagogical competence, the inclusive orientation construct captures affective commitment and perceived readiness to engage in inclusive teaching. This interpretation aligns with Saloviita's (2022) argument that teachers' support for inclusion is embedded in organisational and systemic conditions that shape professional confidence.

From the perspective of Social Cognitive Theory, these patterns reflect limited mastery experiences and weak social persuasion, two key sources of teacher self-efficacy (Bandura, 1997). Although the *Merdeka Curriculum* promotes learner autonomy and differentiated instruction, participants reported limited opportunities to encounter inclusive science teaching during practicum experiences. Without such experiences, pre-service teachers have little opportunity to develop confidence in adapting scientific activities for diverse learners. Previous research similarly shows that professional confidence and reflective competence develop through socially mediated learning processes and supportive institutional environments (Gu & Day, 2013; Impedovo, 2021; Tschannen-Moran & Hoy, 2001). In this context, inclusive readiness among pre-service science teachers emerges first as an orientation toward inclusion rather than as a fully developed pedagogical capability.

In relation to RQ1, these findings confirm that pre-service teachers generally hold positive attitudes toward inclusive education, although these attitudes are often conditional upon the availability of institutional support and resources.

Conceptual Knowledge and Inclusive Pedagogical Understanding

Although participants express positive orientations toward inclusion, both quantitative and qualitative findings reveal limitations in their conceptual understanding of inclusive pedagogy in science learning. The structural model indicates that conceptual knowledge is positively associated with inclusive orientation, suggesting that a stronger understanding of accessibility, differentiation, and participation supports teachers' readiness to implement inclusive instruction. However, qualitative responses show that this understanding often remains limited to general principles rather than discipline-specific pedagogical strategies.

This pattern is consistent with previous research indicating that conceptual depth in inclusive pedagogy develops through sustained reflective inquiry rather than through exposure to policy discourse or coursework alone (Mouroutsou & Koskela, 2024; Ostrowdun, 2020). In science education, this limitation becomes particularly visible in the absence of inclusive pedagogical content knowledge (PCK), which integrates disciplinary knowledge with strategies that ensure accessibility and meaningful participation in scientific inquiry (Shulman, 2015).

Participants frequently described inclusion primarily in terms of physical access or classroom accommodation. Few responses addressed how scientific ideas might be represented through multiple modes, scaffolded for different learning needs, or assessed through flexible strategies. Differentiation was often framed as a moral responsibility rather than a structured pedagogical approach, while participation was sometimes understood as classroom presence rather than active engagement in scientific investigation. Without explicit opportunities to analyse teaching dilemmas or redesign laboratory tasks for diverse learners, inclusive knowledge remains abstract and disconnected from disciplinary practice.

These findings directly address RQ2 by indicating that pre-service teachers' conceptual understanding of inclusive pedagogy remains limited and insufficiently connected to discipline-specific instructional practices in science education.

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Inclusive Pedagogy in Science Education Contexts

The findings also highlight the difficulty pre-service science teachers experience when translating inclusive concepts into concrete instructional strategies. Indicators originally designed to measure pedagogical practices were based on self-reported and intended instructional behaviours during teaching simulations or practicum experiences. As a result, these indicators capture perceived readiness for inclusive teaching rather than verified classroom practice.

Science education presents particular challenges for inclusive pedagogy because laboratory activities involve specialised materials, procedural routines, and safety considerations. Previous research shows that teacher education programmes often address inclusion as a general pedagogical principle rather than embedding it within subject-specific teaching practices (Fränkel et al., 2023). Similarly, Jones and Burrell (2022) argued that the materiality and procedural norms of science classrooms can unintentionally restrict participation unless inclusivity is deliberately integrated into the design of experiments and inquiry tasks.

Participants frequently expressed willingness to include students with disabilities but struggled to describe concrete strategies for adapting laboratory experiments, modifying learning objectives, or redesigning assessment practices. This pattern suggests that inclusive pedagogical competence requires more than attitudinal commitment. It also requires disciplinary knowledge and opportunities to practise inclusive adaptations in authentic teaching contexts. Dignath et al. (2022) similarly found that pre-service teachers often develop emotional awareness of inclusion earlier than adaptive instructional competence.

Freire's (1970) concept of dialogical praxis helps illuminate this gap. Many participants demonstrate moral awareness of inclusive education, yet they lack opportunities to translate these values into reflective pedagogical action. When teacher education emphasises reflection without structured experimentation and collaborative inquiry, inclusive pedagogy risks remaining symbolic rather than transformative.

Reinterpreting the AKP Gap Through Inclusive Orientation

The revised measurement model provides additional insight into the relationship between attitudes, knowledge, and reported practices. Discriminant validity analysis showed that attitude and self-reported practice indicators were not empirically separable. Instead, they formed a single construct labelled inclusive orientation. This result suggests that self-reported practice items may partly capture affective commitment and aspirational intent rather than demonstrated pedagogical behaviour.

This interpretation helps explain why positive attitudes toward inclusion do not always translate into effective classroom implementation. Previous studies consistently show that supportive beliefs alone do not predict inclusive teaching practices (Almalky & Alrabiah, 2024; Avramidis & Norwich, 2002). In science education, where inclusive implementation requires specialised pedagogical knowledge, material adaptation, and safety-conscious instructional design, the distinction between intention and enactment becomes particularly important.

Social Cognitive Theory explains how supportive orientations can encourage intention without enabling sustained pedagogical action when teachers lack mastery experiences and confidence (Bandura, 1997). Transformative Learning Theory further emphasises the importance of reflective and experiential learning processes in developing inclusive pedagogical competence (Mezirow, 1997). These perspectives suggest that inclusion readiness develops through iterative cycles of reflection, experimentation, and supported practice rather than through attitudinal alignment alone.

The convergence of quantitative and qualitative findings in this study reinforces this interpretation. Participants demonstrate empathy toward learners with disabilities and basic awareness of inclusive principles, yet they report limited capacity to apply these principles within laboratory and inquiry-based science instruction. Inclusive readiness, therefore, represents an early developmental stage that precedes, but does not guarantee, pedagogical competence.

Finally, the reliance on self-reported indicators warrants careful interpretation. Self-report measures provide insight into perceived readiness but do not directly capture classroom behaviour. Previous research highlights a persistent gap between inclusive intentions and enacted teaching practices (Mouroutsou & Koskela, 2024). Self-reports may reflect aspirational thinking or social desirability, particularly when inclusive education is strongly promoted in policy discourse (Opoku, 2022). Future research should therefore combine

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self-report measures with observational and performance-based data to provide a more comprehensive picture of inclusive pedagogical practice.

Conclusion and Implications

This study shows that inclusion readiness among Indonesian pre-service science teachers is expressed more strongly as perceived orientation than as fully developed pedagogical competence. Measurement model results showed that attitude and self-reported practice indicators were not empirically distinguishable and therefore formed a single construct representing teachers' orientation toward inclusive science education.

The structural model further demonstrated that conceptual knowledge of inclusive pedagogy is positively associated with inclusive orientation, while teaching experience contributes indirectly through its relationship with pedagogical knowledge. These findings highlight the importance of conceptual understanding in shaping teachers' readiness to implement inclusive science instruction. However, qualitative evidence revealed that many participants still struggled to translate inclusive principles into concrete teaching strategies, particularly in laboratory and inquiry-based learning contexts.

These results suggest that inclusive readiness in science teacher education develops gradually, with affective commitment sometimes preceding pedagogical competence. Strengthening inclusive science teacher preparation, therefore, requires more than attitudinal support for inclusion. Teacher education programmes should integrate inclusive pedagogy within subject-specific instruction, provide structured practicum experiences, and support reflective experimentation in laboratory and inquiry-based teaching.

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Data Availability Statement

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Declaration of Interest

The authors declare no competing interest.

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